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Analyzing the Commercialization Success of Startups Using the Rough Set Theory (Case Study: Kerman Science and Technology Park)

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Abstract

Today, the issue of commercialization has become a significant concern for all organizations in the business environment. The reason for this importance can be found in the role of commercialization in the final success of a business. The primary purpose of this study is to investigate the influencing factors on the commercialization process of knowledge-based products and predict the probability of commercialization success. Using the extracted rules from this study, the decision-making process of product commercialization will be efficiently facilitated for researchers and managers. The startups established in the Kerman Science and Technology Park (KSTP) constitute the statistical population of this study. The relative preferences of the identified success factors have been evaluated by experts using the network analysis technique. According to the results, the appropriate technology lifespan, political barriers, and awareness and recognition of marketing techniques are the top 3 critical factors. Then, the commercialization information of 100 startups in Kerman Science and Technology Park is analyzed by applying the logic of Rough Set Theory to extract patterns and decision-making rules. Political barriers, appropriate technology lifespan, financial support, finding potential markets, and marketing techniques have been identified as the most important influencing factors. Finally, 18 decision-making rules have been extracted, and 3 rules with the most support and accuracy are validated and proposed.

Keywords: Commercialization success, Business Management, Pattern analysis, Rough set theory, Startup.

1 | Introduction

A successful business idea leads to a sustainable competitive advantage when it reaches the implementation stage and its commercialization profits will be available for the organization and society. In the event of commercialization failure, we will witness the loss of market opportunities and the waste of the organization's

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critical resources. Therefore, decision-makers consider key factors affecting commercialization success and evaluate its potential as primary concerns [1]. Some of the most important factors identified concerning the issue of product commercialization success for startups are laws and regulations, political, economic, cultural, technological, financial, marketing, market size, human resources, organizational structure, knowledge, and skills. The results of research studies indicate that a broad scope of factors is influential in achieving commercialization success [2]. This extensive and diverse domain can change the potential influence of other key factors that play a vital role in the business environment. The relative importance of these influential factors can also vary (*Table 1*). For instance, Mohseni Rad and Rabiei [3] prioritized factors affecting the success of established startups in the Alborz Science and Technology Park. The results showed that law and marketing factors were ranked as the most and least influential in the new product development business process. Tari et al. [4] categorized influential individual, organizational, and environmental factors. The results indicated that environmental and government factors were the most influential in commercialization success. The aforementioned results are affected by the organization's efforts to achieve commercialization success, accompanied by many challenges such as the results being less than expected and desirable outcomes. These conditions indicate that the commercialization process complexity is affected by multiple factors with uncertain and unknown potential relationships [5].

On the other hand, the complexity of the commercialization process analysis and numerous influential factors make it difficult to predict the probability of commercialization success. Despite studies on identifying and prioritizing influential factors in commercialization success, few studies have focused on evaluating and analyzing successful commercialization models. This study aims to identify, categorize, and explore the influencing factors on commercialization success and the success model of product commercialization in startups. Based on the extracted rules, this will help estimate the probability of commercialization success in the considered business environment. Applying the aforementioned analysis is necessary to assess the commercialization success before introducing a product to the market and avoid uncertain situations.

It should be noted that technical efficiency alone is not sufficient. If an idea fails during or after the commercialization process, it can result in a loss of financial and spiritual capital for the organization. For this purpose, active startups in Kerman Science and Technology Park (KSTP) have been selected as a case study. Kerman province benefits from access to substantial natural resources and the presence of large industrial companies, creating a favorable environment for the establishment and growth of new companies to complement existing value chains. Therefore, providing suitable conditions to support newcomers in a business environment is crucial. Using an appropriate assessment model for predicting success, available resources can be efficiently allocated to startups. Based on the suggestion of KSTP managers, the issue of identifying key success factors in the commercialization process of startups has been considered.

The first step involves investigating the decision support environment for these companies as a research problem. Additionally, the potential for making informed decisions and predicting organizational performance based on available information and current records can enhance the efficiency of decisions related to the commercialization process. Therefore, the focus has been on identifying and studying key factors that influence the success or failure of the commercialization process. By analyzing and prioritizing these factors, it is possible to determine strategies for success in the commercialization process and develop corresponding rules that can assist startups in managing their product commercialization. These rules can also aid supportive organizations in determining the necessary level of funding to support startups. To achieve this, the rough set technique is utilized as an analytical tool for decision-making and pattern recognition. This study aims to answer how to analyze the success pattern in the commercialization process of startups using the rough set theory in the KSTP as a case study.

2 | Literature Review

The survival of startups and the acquisition of sustainable competitive advantages depend on triumphant commercialization success. This success presents additional challenges for startups, particularly those that are

knowledge-based. The significance of this issue has led to numerous studies examining the key factors influencing the commercialization success of startups. In a descriptive-correlational study, Pakniyat et al. [6] investigated the impact of various factors on the commercialization process by examining companies located in the Isfahan Science and Technology Park as a case study using structural equation analysis. The findings suggest that factors such as learning ability, research and development, strategic planning, organization, and production have a confirmed impact on commercialization in these companies. In contrast, marketing ability and resource allocation do not play significant roles.

Additionally, the results demonstrate technology commercialization's positive and significant effect on company performance. Khayatian et al. [7] explored the sustainability of knowledge-based companies by gathering expert opinions through a questionnaire. They utilized statistical methods, including correlation analysis, covariance matrix analysis, path analysis, factor analysis, and structural equation modeling, to test their conceptual model. The results indicate that financial outcomes, market, innovation, and entrepreneurship are the main components of company sustainability. Furthermore, the research reveals that internal organizational factors such as individual factors of founders, corporate factors, and external factors related to business characteristics and system innovation influence the sustainability of knowledge-based companies. Mansuri et al. [8] prioritized key drivers affecting startup development in Kerman province using statistical analysis based on Friedman's test, including factors related to technology, culture, social aspects, human resources, support, government, and infrastructure.

Yazdimoghaddam [5] proposed a commercialization potential strategy evaluation model based on technology strategy evaluation and commercialization readiness evaluation models, highlighting market characteristics as the most crucial dimension for technology commercialization success. Azad et al. [2] examined the general challenges of product commercialization in startups in Iran, focusing on marketing and financial sectors, including laws, regulations, political, economic, cultural, technological, financial, marketing, size, human resources, organizational structure, knowledge, and skills. These factors are significant challenges to successfully commercializing new products startups offer. Barani and Koshtegar [9] investigated factors affecting commercialization based on literature review findings, emphasizing the importance of achieving economic development as a facilitator of commercialization and highlighting the need for a strong relationship between universities and industries.

The development of a model to predict the success of commercializing new products in Iran has been explored in only a few studies. Bandarian [10] assessed the commercialization potential of research projects using fuzzy logic for environmental analysis. The technology strategy evaluation model is utilized to determine this potential. The success of commercializing a new product is evaluated at three levels: optimistic, pessimistic, and most probable. However, the weakness of this model lies in its limited evaluation of components that impact commercialization success, leading to a probability of success based on only a small set of factors. The complexity of the commercialization process is attributed to the extensive factors that influence it. Mirghafoori et al. [1] examined models for predicting the success of commercializing new products using neural network methods. Through literature review findings and expert opinions from a statistical community of 400 inventors research data analysis was conducted in two parts: testing research hypotheses and identifying influencing factors on commercialization and analyzing data using artificial neural networks to create a prediction model. The results indicate that individual, technical, market, financial, and administrative factors all impact commercialization success, with the multilayer perceptron model performing the best among neural network models. Zahedi et al. [11] proposed an integrated approach to analyze and develop strategic options, evaluating and prioritizing influential factors in commercialization and formulating implementation strategies for each factor. Mirghfouri et al. [1] further investigated commercialization models in the literature using the foundation data method, focusing on knowledge-based companies in Tehran. Tari et al. [4] studied factors influencing the growth and success of knowledge-based companies based on expert opinions from twenty CEOs of successful companies in Isfahan, identifying individual, environmental, and organizational factors as key to success. Mohseni Rad and Rabiei [3] prioritized factors affecting the

commercialization of knowledge-based products through an exploratory factor analysis questionnaire. Soltani Fesaghandis et al. [12] predicted the success of new product development using factor analysis and artificial neural networks, identifying key factors in the success of new product development. A strategic map for the commercialization of new technologies in technology-based companies was developed, outlining five main strategies [10], [13]. Agha [15] examined factors affecting the success of startup businesses in North America, focusing on preparation, team, product, financing, targeting, execution, and external factors. Kim et al. [14] ranked the key factors influencing startup business design, with commercialization as the most essential factor. Momayez [15] studied factors affecting the commercialization success of startups in Tehran science and technology parks, focusing on product features, financial resources, marketing, business services, laws, marketing processes, training, and product standardization. Christensen and Bengtsson [16] investigated factors affecting the commercialization of startups in the semiconductor industry.

Saura et al. [17] identified critical factors influencing startup success through social networks and user-generated content. Díaz-Santamaría and Bulchand-Gidumal [18] explored the econometric estimation of factors influencing startup success financially. Shahraki Moghadam and Farsijani [19] identified dimensions and criteria for promoting Internet-based startups using the fuzzy Delphi technique. Asgari et al. [20] identified critical success factors for startups using sentiment analysis and data mining techniques. Santoso et al. [21] analyzed factors influencing the success of startup business incubation programs. Zhao et al. [22] proposed a framework for analyzing critical success factors through the startup lifecycle. Recent studies have applied quantitative analysis methods, including Rough set theory and multi-criteria decision-making methods [23–29]. Despite the importance of analyzing commercialization success, few studies have been conducted to examine these factors and provide an inclusive model to aid decision-making. Therefore, there is still a need to develop comprehensive models that include a diverse and wide range of success evaluation criteria. Additionally, it is highly desirable to utilize effective methods to analyze success factors and extract related patterns. This study aims to extract practical rules to predict commercialization success through a comprehensive success evaluation model based on the rough theory.

Table 1. Influential factors on startup commercialization success based on the literature review.

Factors	Measures	References
Individual	The personality type of the innovator, management experience, entrepreneurial experience, relevant industry experience, thorough understanding of business and trade processes, willingness to accept the risk of commercialization failure, document experiences in product commercialization, motivation, dedication to the commercialization process, lack of a second job and availability of time, industrial knowledge, promotion of commercialization culture, and ability to manage multiple innovation projects simultaneously are all essential for successful product commercialization.	[4], [30]
Demographic	Number of commercialized designs, average time to commercialization, primary purpose of the inventor, reasons for registering the idea, suitable location for carrying out activities, average number of people involved in the design or invention process, age, gender, marital status, occupation, level of education, and field of study.	[4], [30]
Technical	The country's potential for large-scale scientific and technical product production depends on several factors. These include the longevity of the technology resulting from the invention, which can prevent the rapid obsolescence of the product. Additionally, having a strong and skilled research team is essential to address any technical or scientific defects in the invention. Support from a robust research and consulting team and access to resources like Maher can significantly aid in the commercialization of ideas. Collaboration between researchers, inventors, and commercialization executives is crucial. Moreover, the speed of technological advancements and the availability of appropriate infrastructure and technical laboratories play a significant role in determining the success of product production on an economic scale.	[3], [30]

Table 1. Continued.

Factors	Measures	References
Market	To successfully launch a product, it is crucial to have a reliable and stable market demand and a deep understanding of key marketing tools and techniques. It is essential to assess the product's appeal from the customer's perspective, ensuring that it meets their needs and desires. Before finalizing the idea and entering the market, evaluating the market potential and comparing pricing with similar products is essential. Additionally, the product should be user-friendly and easier to use than competitors. Developing a solid market entry strategy and conducting thorough market research to identify potential markets are also key to success.	[3], [13], [30]
Financial	The viability of the owner's commercialization plan, along with support and financial and intellectual investment from the government and private sector, are crucial factors. Additionally, the private sector's trust in inventors to purchase their ideas is essential for successful commercialization. Other important considerations include investment funds, foreign investors, rate of return on investment, profit margin, claims, and annual financial turnover.	[3], [4], [30]
Administration and rules	The absence of extensive and cumbersome administrative laws and regulations for commercialization and formation of production enterprises, the lack of political obstacles like sanctions on raw materials and technology, the absence of fear regarding the disclosure of ideas, and the lack of valid intellectual property rights laws in the country, all contribute to an environment that fosters innovation. Additionally, having a comprehensive information base, nationwide patents, and registered ideas to acknowledge the novelty of ideas further enhances this environment. Furthermore, laws that support the sale of products, incentive laws to encourage buyers, and the ability to obtain competitors' standards and technical licenses all play a significant role in promoting a thriving business.	[3], [30]
Organizational	A team of commercialization specialists is responsible for establishing connections with external resources, organizing commercialization capabilities efficiently, coordinating effectively in research and development, marketing, and production, identifying strengths and weaknesses, implementing a robust mechanism for technology transfer from research to product development, facilitating large-scale market transfers, and incorporating customer feedback into the technological innovation process.	[3], [30]

3 | Research Method

This study is practical and quantitative in nature, based on its purpose and methodology. Library research methods were used to gather information from relevant literature. Additionally, interviews and questionnaires were utilized to collect necessary data on the commercialization success of understudied startups, following the rough set theory. Ten senior managers and experts from the KSTP were chosen to identify and prioritize key success factors. After experts confirmed the influential factors on commercialization, all startups within the KSTP were evaluated. The process of analyzing and extracting rules using the rough set theory is illustrated in *Figs. 1* and *2*, respectively.

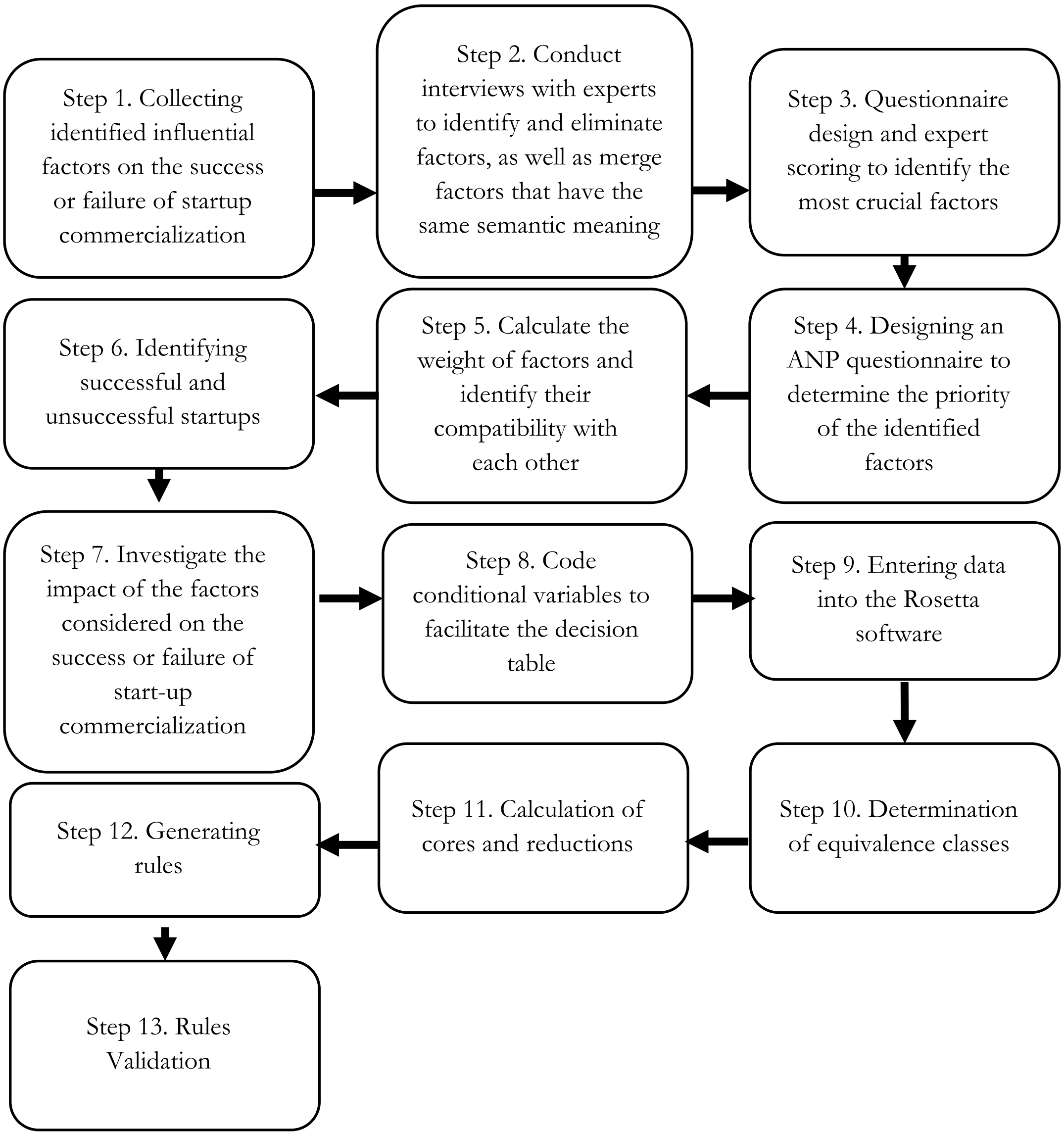


Fig. 1. Steps of the applied research method.

Step 1. Potential factors influencing the success of commercializing startups, as identified in the literature, are reviewed and approved by experts. Ineffective factors are eliminated, and factors with similar meanings are combined. The remaining factors are evaluated by experts in terms of importance and likelihood of occurrence using a five-point Likert scale. The experts' opinions are then analyzed to determine the priority of the identified factors. *Relation 1* is the final index identifying the most crucial and uncertain factors.

$$\text{IndexValue} = \left(\frac{\sigma\ \text{prob.of occ.} - \min(\sigma\ \text{prob.of occ.})}{\max(\sigma\ \text{prob.of occ.}) - \min(\sigma\ \text{prob.of occ})}\right) \times \left(\frac{\bar{x}\ \text{Import} - \min(\bar{x}\ \text{Import})}{\max(\bar{x}\ \text{Import}) - \min(\bar{x}\ \text{Import})}\right). \quad (1)$$

σ prob. of occ: standard deviation of the probability of occurrence for each factor.

$\min(\sigma$ prob. of occ.$)$: the smallest value of the standard deviation of the occurrence probabilities.

$\max(\sigma$ prob. of occ.$)$: the maximum value of the standard deviation of the occurrence probabilities is needed.

$\bar{x}$ Import: average importance of each factor.

$\min(\bar{x}$ Import$)$: the lowest value of average importance.

$\max(\bar{x}$ Import$)$: the highest average importance value.

Step 2. After identifying the most important influential factors using the final index, we will use the network process analysis technique to calculate the weights of these factors. The inconsistency rate of each pairwise

comparison matrix should be less than 0.1. then, the pairwise comparisons made by experts will be consolidated using the geometric mean method to determine the final relative weight through the network process analysis method.

Step 3. We will determine successful and unsuccessful startups based on the case study. Next, we will investigate the impact of these identified factors on the success or failure of startups through a questionnaire. Finally, we will use the gathered information to analyze and extract patterns using the associative rules of rough set theory with the assistance of Rosetta software.

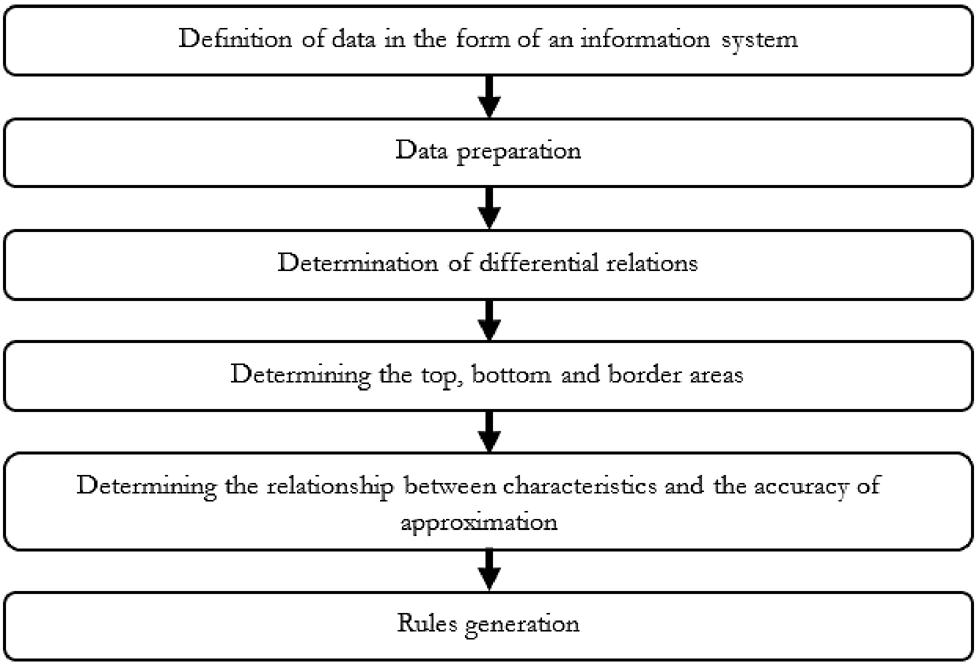


Fig. 2. The steps of developing rules using the Rough set theory.

Details of the applied rough set theory are presented as follows (*Fig. 2*).

Data definition

In rough set theory, rows and columns represent objects and variables (i.e., characteristics) in the information table, respectively. An information system is presented as S=(U, A, V, F) in rough set theory. Here, U={U1, U2,..., Um} is a non-zero and finite set of objects, while A={a1,a2,..., an} is a non-zero and finite set of characteristics. Van={a1n+a2n+a3n+...+amn} is the value set containing all the quantitative or qualitative values for each object and its corresponding characteristic. F represents an information function (*Eq. (2)*).

$$F = \mathrm{U}^{*}\mathrm{A}\ \mathrm{a} \in \mathrm{A}, \mathrm{V} = \mathrm{U}V_a\ , \mathrm{F}(\mathrm{x}, \mathrm{a}) \in \mathrm{Va}, \forall \mathrm{a} \in\ \mathrm{A}, \forall^{*} \in\ \mathrm{U}. \quad (2)$$

In this study, characteristics are the most important factors affecting the success of startup companies. The decision characteristic determines the success or failure of the company. One of the startup companies in the Kerman Science and Technology Park is the object of study. The value set contains information on the startup company for each conditional characteristic.

Non-distinction relationship

The concept of non-distinction is fundamental in Rough Set theory, representing the relationship between two or more objects or members where all the values associated with the desired subset of characteristics are identical. An indistinguishable relation is considered an equivalence relation, treating all identical objects within a set as primitive data. In this scenario, for each assumed variable P, there exists an equivalence relation as follows:

$$\mathrm{IND}=\{\ (\mathrm{X},\mathrm{Y}) \in \mathrm{U} * \mathrm{U}: \forall_{\mathrm{a}} \in \mathrm{P}, (\mathrm{X}, \mathrm{a}) = \mathrm{f}(\mathrm{y}, \mathrm{a})\ \}. \quad (3)$$

Objects that share a common feature are grouped into an equivalence class. The collection of all equivalence classes of the IND relation is denoted by (U|IND).

Determining the upper, lower, and borderline approximations

Rough set theory is recognized as a standard framework for extracting information from data and considers the acquired and categorized knowledge as part of the dataset. Based on the existing knowledge in a system, the belonging of x∈U to the set X⊂U has three possible states: x absolutely belongs to the set X, it does not belong, or it may belong and not belong.

Upper and lower approximations

The upper and lower approximations are inner and outer operations generated by the non-differentiability relation (*Fig. 3*). The lower approximation describes the range of objects that definitely belong to the desired subset. In contrast, the upper approximation includes the set of objects that probably belong to the desired subset. The set X always falls between these two approximations.

$$\underline{\mathrm{apr}}(X) = \cup\{x \in U: \mathrm{IND}(x) \subseteq X\}. \quad (4)$$

The above approximation includes the set of objects that likely belong to the desired subset.

$$\overline{\mathrm{apr}}\,(X) = \cup\{x \in u: \mathrm{IND}(x) \cap X \neq 0\}. \quad (5)$$

The set X always lies between these two approximations, dividing the region U into positive and negative regions. The positive area of X is equivalent to the lower approximation. At the same time, the negative region of X consists of objects that can confidently be said not to belong to set X.

$$\mathrm{Pos}\,(x) = \underline{\mathrm{apr}}(X). \quad (6)$$

$$\mathrm{NEG}(X) = U - \overline{\mathrm{apr}}\,(X). \quad (7)$$

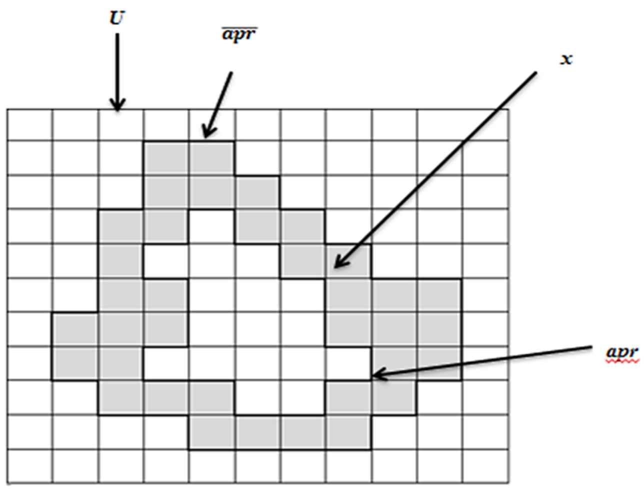


Fig. 3. Upper and lower approximations.

X boundary area

This area contains objects that cannot be reliably identified as belonging to X.

$$\mathrm{BND}_p(X)=\overline{\mathrm{apr}}_p - \underline{\mathrm{apr}}_p(X). \quad (8)$$

Determining the dependence of characteristics and the accuracy of approximation

When considering the non-differentiation relationship, it is important to address key features of the information system, one of which is the dependence of characteristics. The degree of dependence between C and D is represented by a number between zero and one (0 < k < 1), with the value of k being equal to

$$k = \gamma(C, D) = \frac{|POSc(D)|}{|U|}. \tag{9}$$

$$POSc(D) = \bigcup_{x\epsilon\frac{U}{D}} C(X). \tag{10}$$

Determining the kernel and reduction

The variables in RAF analysis can be entirely or partially dependent on each other or have a non-dependent relationship. It determines the main components of the information table. The complete or partial dependence of characteristics is determined using factors k or γ (C, D). The power of classification and differentiation of features in the reduction set is equal to the power of differentiation and classification of all problem characteristics. If P⊆C⊆A and γ c(x)= γ p(x), then set P is called the reduction of set C and denoted as RED (P). Considering the possibility of multiple reductions in the decision table, the common core of all reductions is called the core of the decision table.

$$CORE(P) = \cup_{Ri\epsilon RED(P)} Ri, \quad i = \{1,2, \dots, n\}. \tag{11}$$

Suppose that S=(U, A) is an information system where |U|=n. In this case, each element of the differentiation matrix S with dimensions n×n is determined as follows:

$$d(x, y) = \{a\epsilon A | f(a, x) \neq f(y, a)\}, \tag{12}$$

where d(x, y) is the characteristic set that defines the range of x and y in the given matrix. For each attribute a ∈ A, a boolean variable a is determined. If a(x, y)={a1, a2, ..., ak}≠∅, then the boolean function is expressed as a1 ∨ a2 ∨ ... ∨ ak. In this case, the differentiation function is expressed in the following relationship.

$$f(A) = \prod_{(x,y)\epsilon U} \sum_U a(x, u). \tag{13}$$

The desired matrix built based on the above function is an n×n matrix, where n represents the number of elements and its elements are determined as a set including all the characteristics of the distinct elements of the set [x]i and [x]j. Dij=dji, dij≠0 and the desired matrix are symmetric and lower triangular.

Rules generation

If the set of conditional characteristics is named as conditional classes s and in the form of Xi (i=1,2,...,n) and the set of decision characteristics of decision classes s is presented in the form of Yj(j=1,2,...,n); then the decision rules of C and D can be shown as {RIJ}.

$$\text{If } f(x, q1) = rq1 \wedge f(x, q2) = rq2 \wedge \dots \wedge f(x, qp) = rqp \text{ then } x\epsilon Yj1 \vee Yj2 \vee \dots \vee Yjk \text{ Where } \{q1, q2, \dots, qp\} \supseteq C: \{rq1, rq2, \dots, rqp\} \epsilon\, Vq1 \cdot Vq2 \cdot \dots \cdot Vqp. \tag{14}$$

Validation of rules

The decision support system will utilize two criteria: coverage and accuracy. Coverage refers to the number of observations that meet both the condition of the then part and the condition of the if part, divided by all observations that meet the condition of the then part. Accuracy, on the other hand, is the number of observations that meet both the condition of the then part and the condition of the if part, divided by all observations that meet the condition of the if part.

4 | Results Analysis

Based on literature findings and experts ' opinions, the identified influential factors on a startup's success are presented in *Table 2*. It should be noted that similar high factors are integrated, and low influential factors are removed from the final list.

Table 2. Final identified influential factors on the commercialization success of the startups.

Factor	Measures
Technical	The possibility of scientific and technical product production in the country on an economic scale. Appropriate lifespan of the technology resulting from the invention, which prevents the expansion of the invention. Strong and skilled research and consulting team support to support idea commercialization. The existence of suitable infrastructure and technical laboratories.
Market	Knowledge and understanding of key tools and techniques necessary for proper marketing of products. Identifying the attractiveness of the product from the point of view of customers to buy the product. Check the plan before registering the idea in terms of market potential. Functionality and lack of complexity of the product compared to similar products in the market. Initial market entry strategy. Ability to search and find potential markets for the product.
Financial	Financial and intellectual support and investment from the government and the private sector for commercialization. Private trust to inventors to buy their idea points for commercialization investment funds.
Administration and rules	Absence of extensive and cumbersome administrative rules and regulations for commercialization and establishment of production companies. Absence of political obstacles, such as sanctions on raw materials and technology. The existence of a comprehensive and nationwide database of registered inventions and ideas to recognize the novelty of the idea.
Organizational	Number of commercialization specialists. Good links with external resources. Appropriate organization of capacities in the direction of commercialization. Good coordination in research and development, marketing, and production. Knowing the strengths and weaknesses. A good mechanism for technology transfer from research to product development. Transmitting high volumes of market and customer feedback to the technological innovation process.

Then, each identified factor's relative importance and uncertainty were assessed using the Likert scale based on the experts' opinions. Factors with the most significant importance and uncertainty (higher final index value) have been identified as the most important (*Eq. (15)*). The final results of factor evaluations are shown in *Table 3*. The value of the considered index function is calculated as follows:

$$\text{Index} = \left(\frac{\sigma\,\text{prob.of occ.} - \min(\sigma\,\text{prob.of occ.})}{\max(\sigma\,\text{prob.of occ.}) - \min(\sigma\,\text{prob.of occ})}\right) \times \left(\frac{\bar{x}\,\text{Import} - \min(\bar{x}\,\text{Import})}{\max(\bar{x}\,\text{Import}) - \min(\bar{x}\,\text{Import})}\right). \tag{15}$$

I. $\sigma\,\text{prob. of occ}$: the standard deviation of the occurrence probability of each factor.

II. $\min(\sigma\,\text{prob. of occ.})$: the lowest value of the standard deviation of the occurrence probability of factors.

III. $\max(\sigma\,\text{prob. of occ.})$: the maximum value of the standard deviation of the occurrence probability.

IV. $\bar{x}\,\text{Import}$: average importance of each factor.

V. $\min(\bar{x}\,\text{Import})$: the lowest mean value of importance.

VI. $\max(\bar{x}\,\text{Import})$: the highest value of average importance.

Based on the factors ranked in terms of the final index, the top eight factors are considered sufficient for the final analysis of the potential network between the most influential factors. *Table 4* presents the pairwise comparison based on the experts' opinions on the most influential factors. A calculated consistency ratio of less than 0.1 indicates appropriate judgment accuracy. *Fig. 4* presents the final calculated importance weights via the ANP method. The obtained results suggest that the proper lifespan of the technology resulting from the invention, which prevents the expansion of the invention, has the first ranking. Political barriers, such as sanctions on access to markets and novel technologies and awareness and recognition of key tools and techniques necessary for proper marketing of products, have the second and third ranks, respectively.

Table 3. Influential factors on commercialization success based on the final index assessment.

Rank	Factor	Probability			Importance	Index
		Average	Mean	σ		
1	Political obstacles	2.71	3	1.7	4.29	0.98
2	Appropriate lifespan of technology	3.14	3	1.35	4.14	0.67
3	Marketing techniques	3.74	4	1.6	4.00	0.65
4	Financial support	3.71	4	1.11	4.28	0.54
5	Functionality and lack of complexity	3.00	3	1.29	4.14	0.51
6	Identify the attractiveness of the product	3.57	4	1.27	4.14	0.51
7	Finding potential markets	2.86	3	1.35	4.00	0.51
8	Link with external resources	2.86	3	1.35	4.00	0.50
9	The possibility of producing a product from a scientific point of view	3.57	4	1.27	4.14	0.39
10	Transmit high-volume feedback	2.86	3	1.35	4.00	0.31
11	The existence of suitable infrastructure and technical laboratories	2.86	3	1.35	4.00	0.31
12	Examining the plan before registering the idea in terms of market potential	3.29	4	1.25	3.86	0.19
13	Initial market entry strategy	3.71	3	0.95	4.00	0.19
14	Private trust for inventors	3.14	4	1.21	3.86	0.18
15	Investment funds	3.14	3	0.90	4.00	0.17
16	Foreign investors	3.29	3	0.76	4.14	0.16
17	Absence of extensive and cumbersome laws and regulations	3.14	3	1.07	3.86	0.15
18	Comprehensive information base	2.86	3	1.07	3.86	0.15
19	Number of commercialization specialists	3.86	4	0.90	3.86	0.11
20	Appropriate organization of capacities	3.14	3	0.69	4.00	0.11
21	Knowing the strengths and weaknesses	3.86	4	0.69	4.00	0.10
22	A good mechanism for technology transfer from research to product development	2.86	3	1.21	3.71	0.10

Table 4. Pooled results of pairwise comparisons of criteria.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	0.803	1.154	1.415	1.089	1.247	1.301	1.068
C2	1.245	1	1.088	1.38	1.621	1.585	1.823	1.246
C3	0.867	0.919	1	1.079	1.475	0.896	1.122	1.112
C4	0.707	0.725	0.927	1	1.54	0.922	1.184	0.803
C5	0.553	0.617	0.678	0.649	1	0.683	0.535	1.278
C6	0.802	0.631	1.116	1.085	1.464	1	0.823	0.644
C7	0.769	0.549	0.891	0.845	1.869	1.215	1	0.586
C8	0.936	0.803	0.899	1.245	0.782	1.553	1.706	1

After identifying and analyzing key influential factors on startup success, the business performance of 100 startups in the KSTP was analyzed using rough set theory. The logical rules applied were extracted and analyzed using Rosetta software, and the logical connections between the gathered information were examined. For this purpose, coded conditional and decision variables based on experts' opinions were presented in *Tables 5-7*. In this study, all the considered data are discrete, and categorizing them is unnecessary.

The concept of non-differentiation is fundamental in rough set theory, implying the relation between two or more members where all values related to the desired characteristics subset are the same.

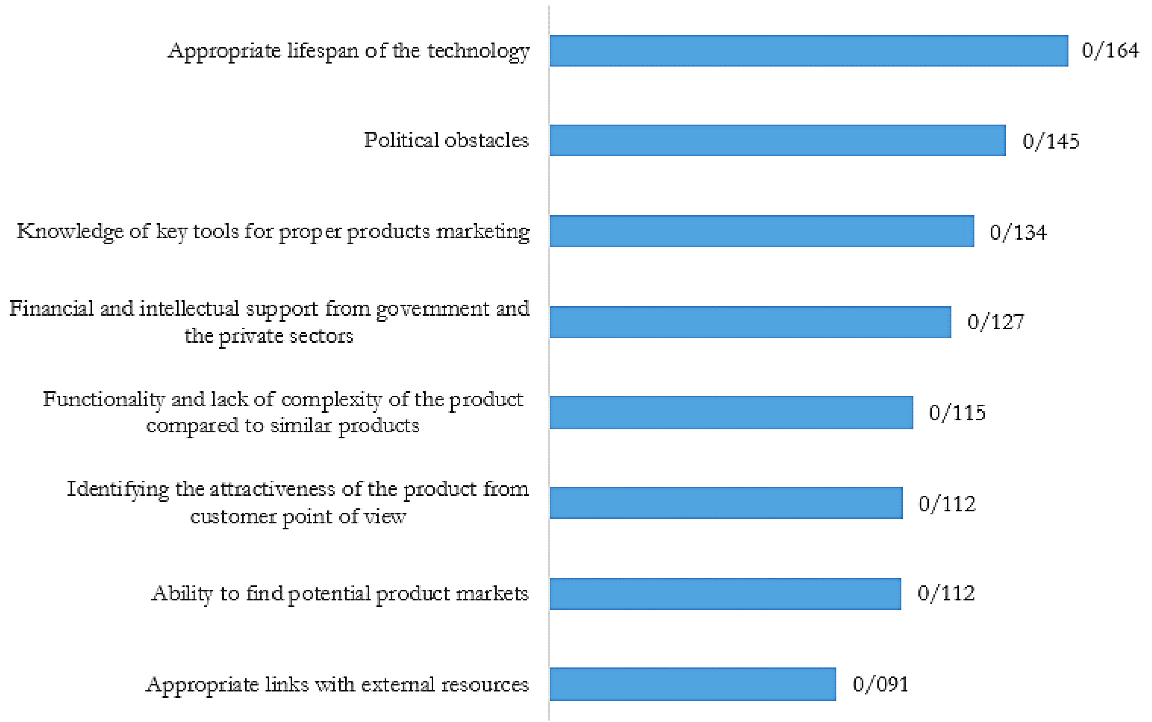


Fig. 4. Final weights of criteria.

An equivalence relation treats all the same objects in a set as primitive data; for each assumed variable P that P⊆A, an equivalence relation in the form of *Eq. (16)* is considered.

$$\mathrm{IND} = \{(x, y) \in U \times U, \text{for all } \alpha \in P, f(x, \alpha) = f(y, \alpha)\}. \quad (16)$$

Eq. (16) states that the value of objects X and Y in the desired characteristic is indistinguishable. Therefore, objects with the same characteristics are grouped into an equivalence class. The family of all equivalence classes of the IND relation is represented by (U|IND). The Rosetta identifies the equivalence class based on the amount of data, as shown in *Fig. 5*.

Table 5. Examples of regarded data, conditional, and decision variables.

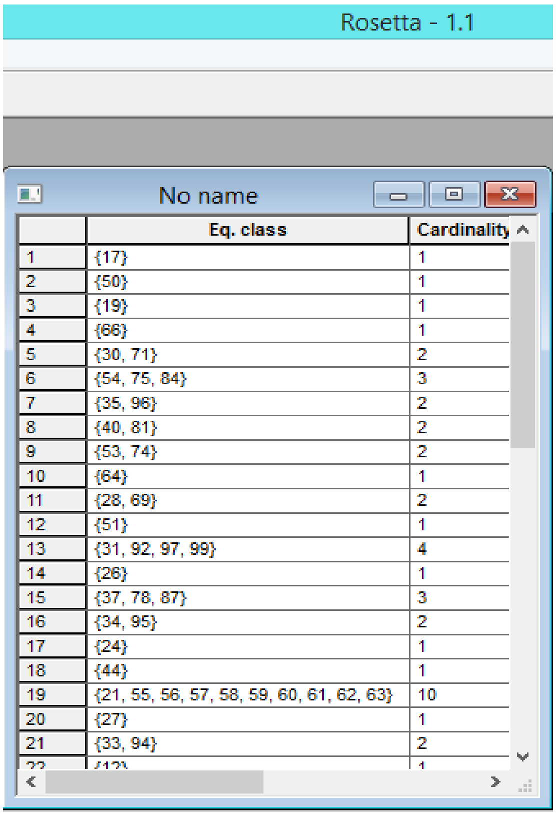
	Verified Conditional Variables Via Experts								Decision Variable
	Political Obstacles	**Appropriate Lifespan of Technology**	**Financial Support**	**Functionality and Lack of Complexity**	**External Links**	**Attractiveness of the Product**	**Finding Potential Markets**	**Marketing Techniques**	**Successful or Unsuccessful Company**
1	It was very influential and caused the commercialization of the products to fail	5 years and above	Very low	Workability and lack of complexity were much better than competitors	Not at all	Low	To some extent	Low	Unsuccessful
2	It did not affect the success or failure of commercialization of the products	1 to 2 years	To some extent	Workability and lack of complexity were at the same level as competitors	Not at all	Low	Not at all	Not at all	Successful
3	It was very influential, but it did not cause the commercialization of the products to fail	Products manufactured like ours have already been marketed by competitors	Very high	Workability and lack of complexity were at the same level as competitors	Low	Low	Low	Low	Successful
4	It did not affect the success or failure of commercialization of the products	2 to 5 years	Very low	The products were completely innovative and there was no competitor in the market	Low	High	To some extent	Low	Unsuccessful
5	It was very influential and caused the commercialization of the products to fail	5 years and above	To some extent	Workability and lack of complexity were at the same level as competitors	Not at all	To some extent	To some extent	Not at all	Successful
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	It did not affect the success or failure of commercialization of the products	5 years and above	To some extent	Workability and lack of complexity were at the same level as competitors	Not at all	Low	Not at all	Not at all	Unsuccessful

Table 6. Coding of conditional variables.

Conditional Variable	Code 1	Code 2	Code 3	Code 4
Political barriers	It was very influential and caused the commercialization of the products to fail	It did not affect the success or failure of commercialization of the products	It was very influential, but it did not cause the commercialization of the products to fail	It was very influential and made the commercialization of the products successful
Product life cycle	1 to 2 years	2 to 5 years	The products are not new and have already been introduced by competitors	5 years and above
Work capability and no complexity	Workability and lack of complexity were much better than competitors	Workability and lack of complexity were at the same level as competitors	Workability and lack of complexity were low on par with competitors	The products were completely innovative and there was no competitor in the market

Table 7. Decision variable coding.

Conditional Variable	Successful Company	Unsuccessful Company
Code	YES	NO



	Eq. class	Cardinality
1	{17}	1
2	{50}	1
3	{19}	1
4	{66}	1
5	{30, 71}	2
6	{54, 75, 84}	3
7	{35, 96}	2
8	{40, 81}	2
9	{53, 74}	2
10	{64}	1
11	{28, 69}	2
12	{51}	1
13	{31, 92, 97, 99}	4
14	{26}	1
15	{37, 78, 87}	3
16	{34, 95}	2
17	{24}	1
18	{44}	1
19	{21, 55, 56, 57, 58, 59, 60, 61, 62, 63}	10
20	{27}	1
21	{33, 94}	2

Fig. 5. Elements in each class.

The core and residual measures are analyzed after coding the conditional and decision variables. The core features include the most important and influential ones. Removed variables do not affect the equivalence relations. Additionally, an approximation of the sets is identified, and by removing some variables, the developed decision table becomes simpler. In this study, the features in the core are defined as follows:

Core={political barriers, appropriate technology lifespan, financial support, finding potential markets, marketing techniques}.

Decision rules are in the form of if (conditions) and then (results), indicating a kind of dependence between conditional criteria and decision criteria. The results of the genetic algorithm implementation have been extracted as rules. If the strategy for generating rules is to obtain the entire set of rules from the redundant ones, we first obtain the redundant ones using the ORR method and then enter the selected characteristics with the help of the Manual-R method. Then, all potential rules are obtained. With the help of rough set theory, 18 logical rules have been extracted. Some of the proposed rules have weak support factors. Among these, only 3 rules with the most repetition and according to other validation rules have been selected, as shown in *Fig. 6* and *Table 8*.

Table 8. Extracted logical rules.

Rules
Rule 1: if (political barriers=1) and (product life cycle=1) and (financial support=2) and (finding potential markets= 3) and (marketing techniques=2) then (unsuccessful). Description: if a startup is heavily impacted by political obstacles that influence its success or failure in commercialization, especially in its early years (1 to 2 years) when financial support from both the government and private sector is limited, and if the Startup shows a high ability to identify potential markets, as well as a strong knowledge and understanding of marketing techniques, then the company is likely to fail in commercializing its products or services.
Rule 2: if (political barriers=2) and (product life cycle=1) and (financial support=5) and (finding potential markets=3) and (marketing techniques=3), then (successful). Description: if a startup is not significantly impacted by political obstacles in its path to commercialization, and is within its first two years of establishment, and receives substantial financial support from both the government and private sector, and has an average level of understanding of potential markets and marketing techniques, then it is likely to succeed in commercialization.
Rule 3: if (political barriers=3) and (product life cycle=3) and (financial support=3) and (finding potential markets=4) and (marketing techniques=3) then (successful). Description: if a startup faces significant political obstacles that have not led to the failure of product commercialization, and the company is 2 to 5 years old since its establishment, with moderate financial support from both the government and the private sector. If the Startup's ability to understand potential markets is at an average level, and the company's awareness and understanding of marketing techniques is also at an average level, then the company is likely to succeed in commercialization.

There are various statistical indicators to assess the performance of classification rules. The validation matrix is used to select the best rules. In this matrix, the rows represent the actual results, and the columns represent the predicted results. The accuracy of the entire model is shown in this matrix (*Fig. 6*).

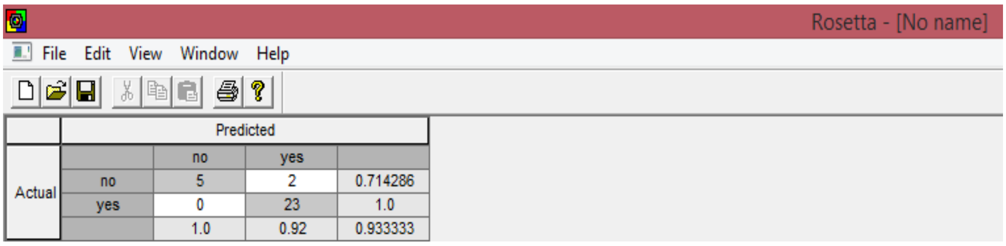


Fig. 6. Rules performance validation results.

The results indicate that the accuracy of all the rules created is 93%. Additionally, the sensitivity and accuracy of each decision group are specified. *Fig. 6* illustrates that the NO decision group has a sensitivity of 71% (5 out of 7 observations belong to the NO decision group and are correctly classified). The coefficient value for the NO decision group is equal to one. In contrast, for the YES decision group, the sensitivity is 92% with a coefficient of one. The prediction accuracy of this model is estimated to be 93%, as shown in *Table 9*.

Table 9. Evaluation of the accuracy of the extracted rules.

Accuracy of Extracted Rules	Output
The predictive power of the successful company	92%
The predictive power of the failed company	71%
Accuracy of the model	93%

Finally, it should be noted that the rough set model is built on the assumption of complete information availability, disregarding any potential gaps or the presence of statistical data. This model, often used for deriving rules in unorganized decision information systems, may appear inadequate. Moreover, the performance metrics considered (i.e., crucial factors influencing startup success) were determined by reviewing literature and expert input. These metrics could apply to other case studies as well. Furthermore, the findings from analyzing commercialization success and decision-making rules could be broadly applied to a comparable population of startup enterprises.

4.1 | Managerial Insights

Providing specialized commercialization services: in today's highly competitive business environment, developed countries have taken steps to promote specialized companies in the field of commercialization. Despite the need for such companies in Iran, limited companies specialize in commercialization. Financial and non-financial support is available for startups seeking commercialization services. Due to their limited resources, startups must have easy, fast, and cost-effective access to these services. For instance, part of the financial support for startups can be allocated to consulting companies that provide mentoring and coaching services for commercialization. Networking between existing companies and startups is also essential to support the commercialization of new products or services and complete the company's value chain.

Using new financing methods: crowdfunding has emerged as a popular method of financing for startups, offering an innovative way to access alternative funds compared to traditional methods. Utilizing these new funding avenues can reduce costs, risks, and the time needed to acquire necessary resources, critical performance indicators for startups. Different types of crowdfunding offer various benefits for startups.

Implementing a matching system: international sanctions in recent years have disrupted companies' sourcing processes by limiting access to global resources. However, some companies possess valuable knowledge, experience, and infrastructure that can benefit startups. The existing population of active companies in Iran can serve as a useful resource to meet the diverse needs of domestic companies. A national matching system can help identify companies' capabilities in different areas and match them with the needs of startups, reducing costs, risks, and time associated with sourcing in the value chain.

Implementing a performance assessment system to predict commercialization success: decision-makers can benefit from predicting companies' future performance based on past performance. Extracting classification rules using methods like rough set theory can aid in the initial assessment of startups and allocate appropriate resources to ensure commercialization success. This decision support system can improve the efficiency and effectiveness of resource utilization.

5 | Conclusion

Commercialization is a crucial yet complex issue for startups entering the business world. The commercialization process significantly affects each Startup's overall performance and success. This study aims to identify and evaluate the factors influencing the commercialization process and predict the likelihood of success in the value chain. Decision-making rules for classifying startups were derived using rough set theory for active startups based on the KSTP. Results obtained indicate the relative importance of factors influencing business success based on experts' opinions, including political obstacles and economic sanctions, the appropriate lifespan of technology and manufactured products that prevent the expansion of other inventions, knowledge and understanding of key tools and necessary techniques for marketing, support and financial investment from the government and private sector, functionality and lack of complexity of the product compared to competitors, identifying the attractiveness of the product from the point of view of customers, finding potential markets, and establishing good links with external resources. Also, considering the relationships between the influential factors, the three most important of them using the network analysis method are the appropriate technology lifespan, political obstacles, and awareness and knowing the key tools and techniques necessary for proper marketing of products. In the next step, by examining the understudied startups via assessment criteria such as the history of the company, the state of the company's growth, total sales, the rate of return on assets, and the number of concluded contracts, the successful or unsuccessful status of each company has been determined. After the initial evaluation of the companies with a questionnaire on the impact of the identified factors on the success or failure of the companies, the collected information was analyzed to extract patterns using association rules based on rough set theory. Factors identified in the core include political barriers, appropriate technology lifespan, financial support, finding potential markets, and marketing techniques. A total of 18 logical rules have been extracted, some of which

have weak supporting factors. Among them, 3 rules with the most repetition and according to other validation rules have been selected. Finally, key research questions are answered as follows:

What factors affect the success or failure of startup companies? Experts in this field conducted interviews to determine the key factors. They removed and integrated many factors and then measured the importance and uncertainty of each factor. The most influential factors were identified using the final index formula. These factors include the absence of political obstacles such as sanctions on raw materials and technology, the appropriate lifespan of the technology resulting from the invention that prevents the expansion of the invention, financial and intellectual support and investment by the government and the private sector for commercialization, workability and lack of complexity of the product compared to similar products in the market, the identification of the attractiveness of the product from the point of view of customers to purchase the product, the ability to search and find potential markets, the knowledge and understanding of the key tools and techniques necessary for proper marketing, and good links with external resources. According to the software output, three factors were removed, and 5 factors were selected as the core influential factors.

What are the most influential factors among these? 1) Absence of political obstacles such as sanctions on raw materials and technology, 2) The appropriate lifespan of the technology resulting from the invention, which prevents the expansion of the invention, 3) Financial and intellectual support and investment from the government and the private sector for commercialization, 4) The ability to search and find potential markets and 5) Knowledge and understanding of key tools and techniques necessary for marketing.

Can the rules extracted from this study serve as a reference for assessing the state of startup businesses at the beginning of their operations? To evaluate the status of a new startup company, the latest observations are first compared to the "if section" of the rules and then categorized according to the "then section." The number of votes that align with each rule is considered to support that rule. With a high % accuracy rate of 93%, these rules can be utilized as a benchmark for evaluating startup businesses based on known variables. In this model, 21 out of 23 successful companies are accurately classified.

To conduct future research, creating a dynamic model that considers the ever-changing nature of the factors that impact business success is recommended. This model should consider causal-infectious loops and potential feedback from the relationships between variables. By doing so, we can evaluate the system's overall behavior during the planning phase. Furthermore, an analysis of the potential interactions between key variables as a complex system could be carried out using the cognitive map technique.

Author Contributions

Conceptualization, S.Sadeghi and A.Hasani.; Methodology, S.Sadeghi and A.Hasani.; Software, S.Sadeghi and A.Hasani.; Validation, S.Sadeghi and A.Hasani; Formal analysis, S.Sadeghi and A.Hasani; Investigation, S.Sadeghi; Resources, S.Sadeghi; Data maintenance, S.Sadeghi.; Writing-creating the initial design, S.Sadeghi; Writing-reviewing and editing, A.Hasani.; Visualization, S.Sadeghi; All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data supporting this study's findings are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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